Experimental El Niño/Southern Oscillation Predictions by the UCLA Atmospheric General Circulation Model (GCM) Coupled to the MIT and POP Oceanic GCMs using the Earth System Model Framework (ESMF)

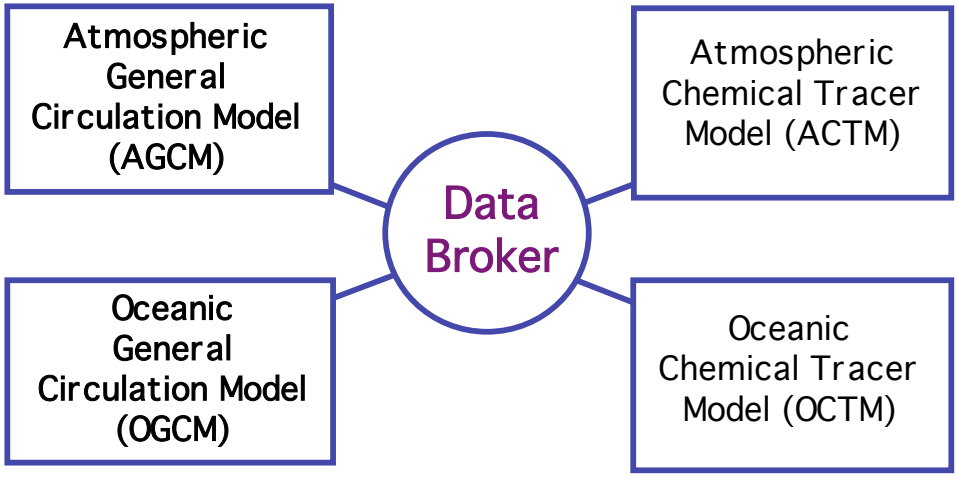
C. R. Mechoso (1), Gabriel Cazes-Boezio (1, 3), J. A. Spahr (1), and D. Menemenlis (2)

(1) *Dept. Atmospheric and Oceanic Sciences, UCLA, USA*
(2) *NASA/Caltech Jet Propulsion Laboratory, USA*
(3) *On leave from IMFIA, Universidad de la Republica, Uruguay*

The ESMF is a structured collection of software building blocks to assist in the development of model components, and to facilitate their assemblage into an Earth System Model.

This talk presents the first independent adoption of ESMF technology.

www.atmos.ucla.edu/~mechoso/esm



UCLA Earth System Model

Model components:

- *UCLA Atmospheric GCM*
- *LANL Parallel Ocean Program (POP)*
- *UCLA ACTM (which can include up to 64 species)*
- *Simple NASA/JPL Ocean Chemical Transport Model*
- *Distributed Data Broker*

UCLA

Increasing the Interoperability of an Earth System Model: Atmospheric-Ocean Dynamics and Tracer Transports NCC4-624

C. R. Mechoso, PI

Major thrusts of the project:

- to further our understanding of an ability to predict the dynamic interaction of physical and chemical processes affecting Earth
- to incorporate the use of NASA data and highlight its importance
- to demonstrate interoperability of codes used in the community of Earth Science.

UCLA

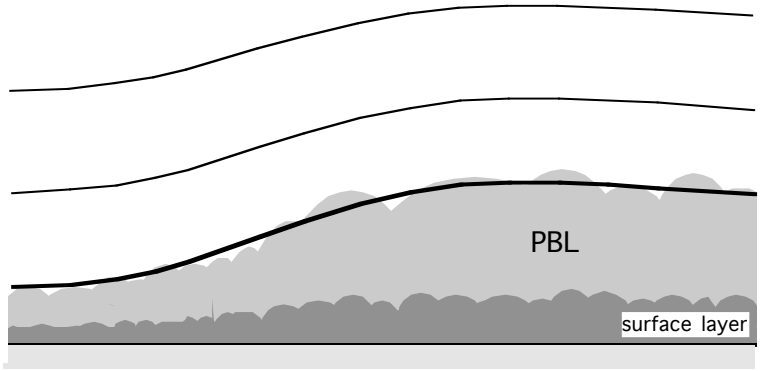
Project Organization

- Tier I: Upgrade the UCLA Earth System Model (ESM). The principal upgrades are in the planetary boundary layer (PBL) parameterization of the AGCM and domain extension of the OGCM. Perform ENSO predictions.

- Tier II: Address issues of code interoperability by using the ESMF services to couple the UCLA AGCM with either LANL POP or the MIT OGCM and by performing forecasts of El Niño/Southern Oscillation (ENSO).

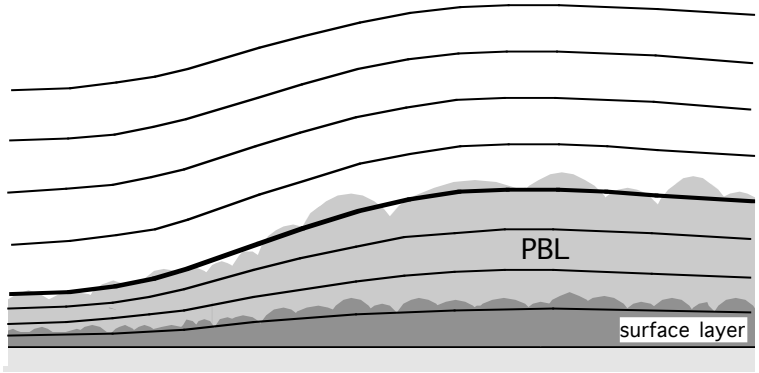
- Tier III: Assess the impact of NASA data by comparing ENSO forecasts using initial states provided by JPL's ECCO project (http://ecco.jpl.nasa.gov). The MIT OGCM is a component in the ECCO's data assimilation system, while POP is not.

Modeling Focus:
PBL in UCLA AGCM



Traditional Framework

Suarez et al. (1983)

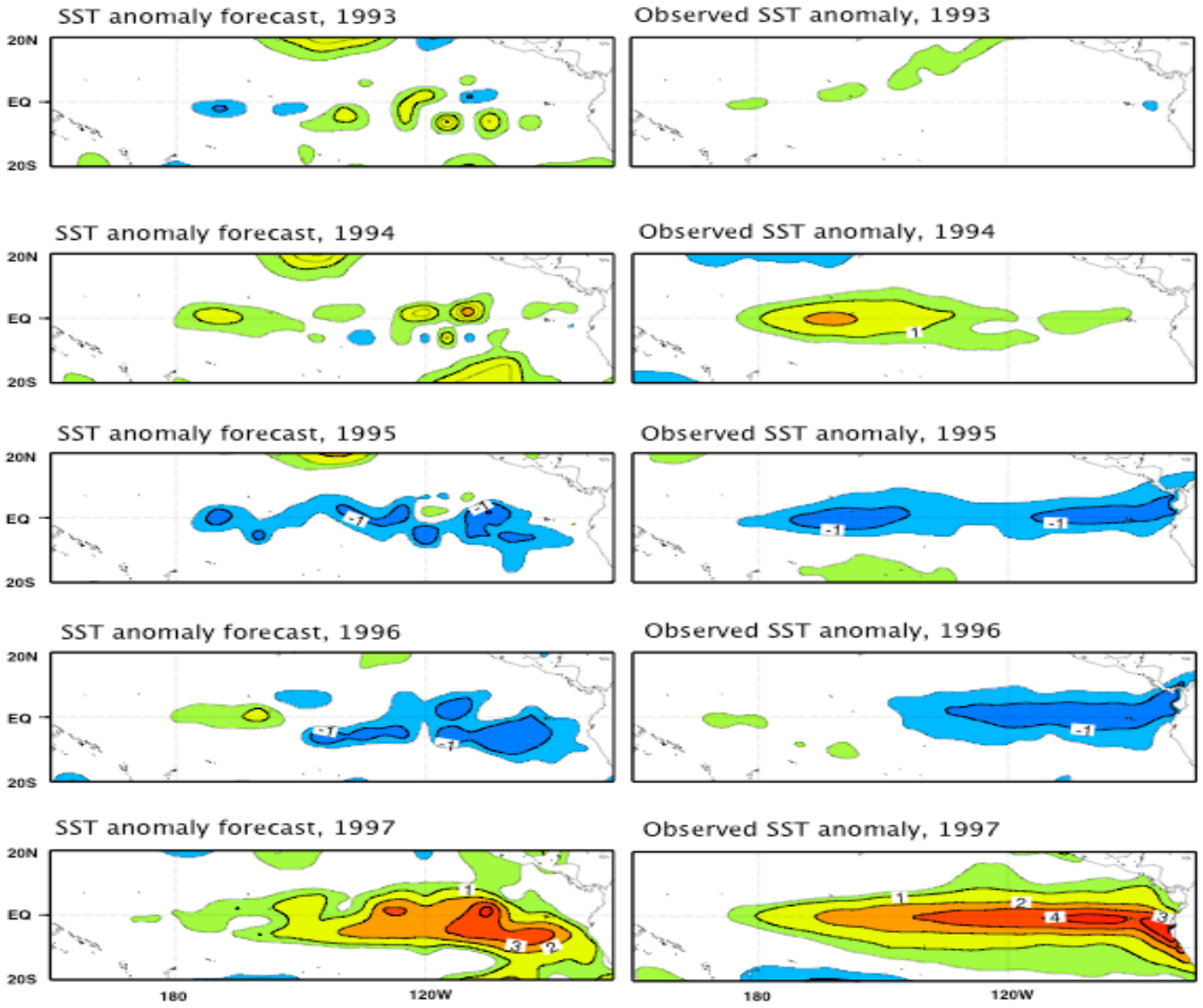


Revised Framework

Konor and Arakawa (2005)

UCLA

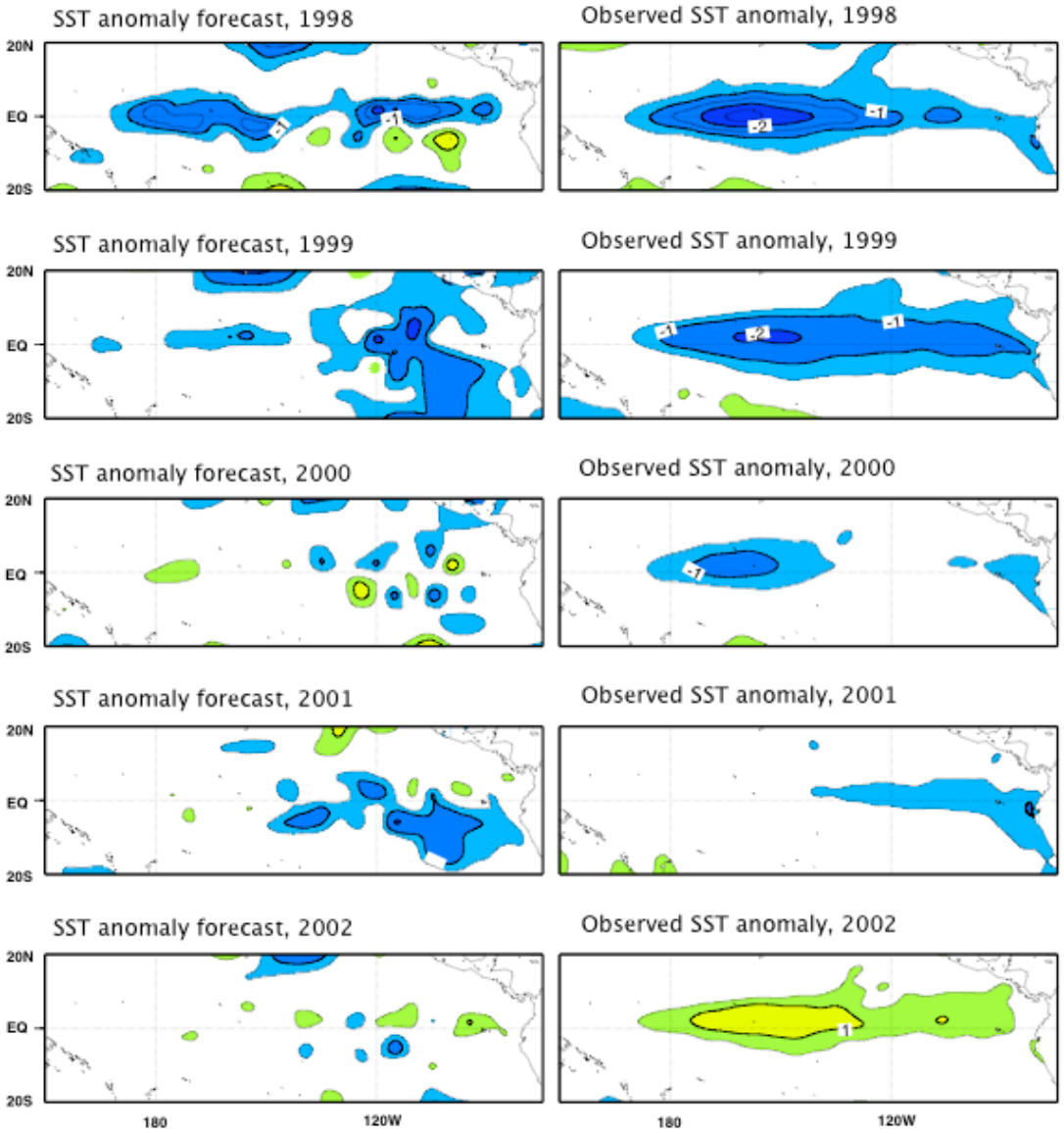
UCLA AGCM - MIT OGCM



Contour interval: 1º C; +/- 0.5º C contours are also shown.

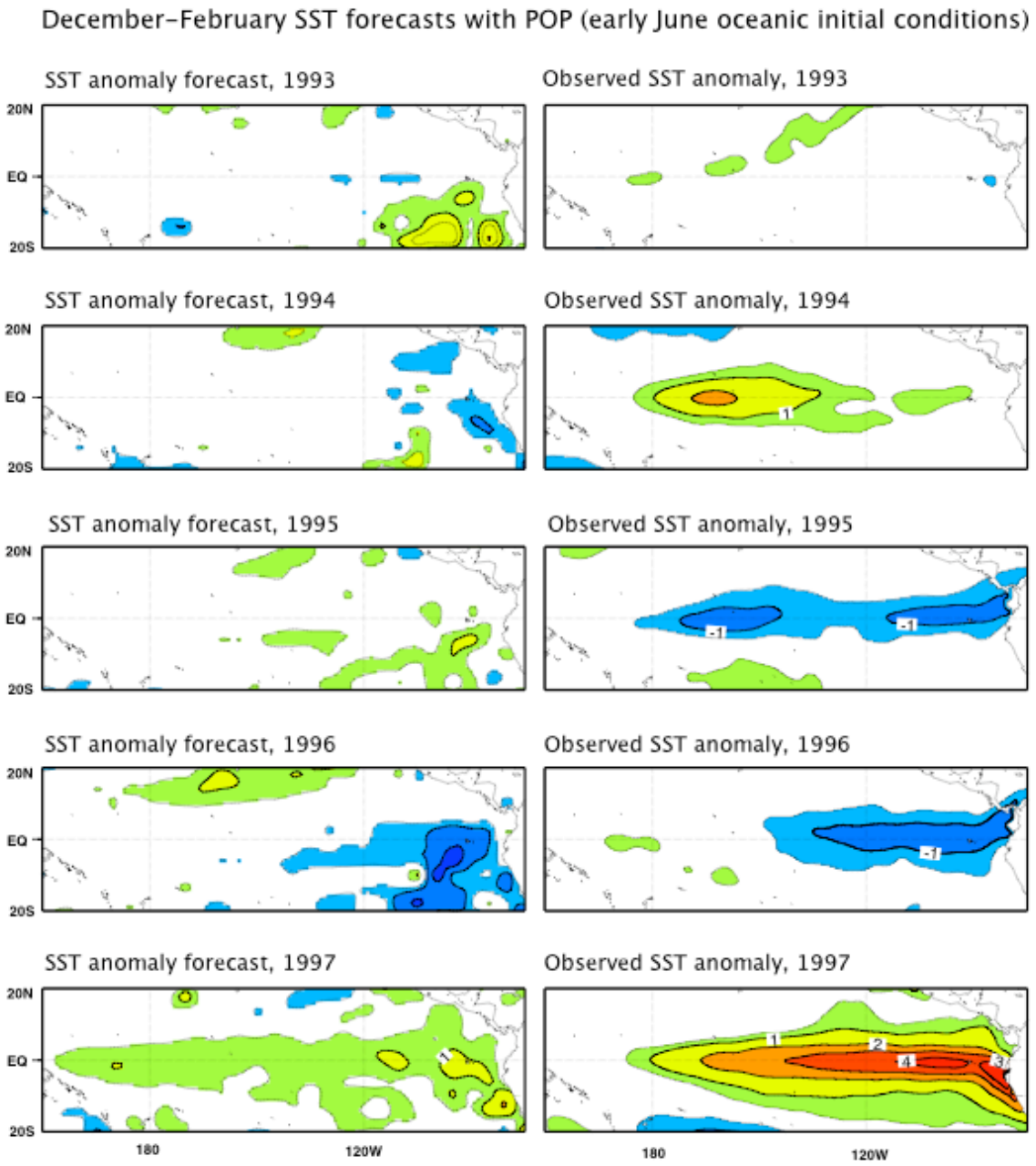
UCLA AGCM - MIT OGCM

December–February SST forecasts initialized with early June oceanic conditions

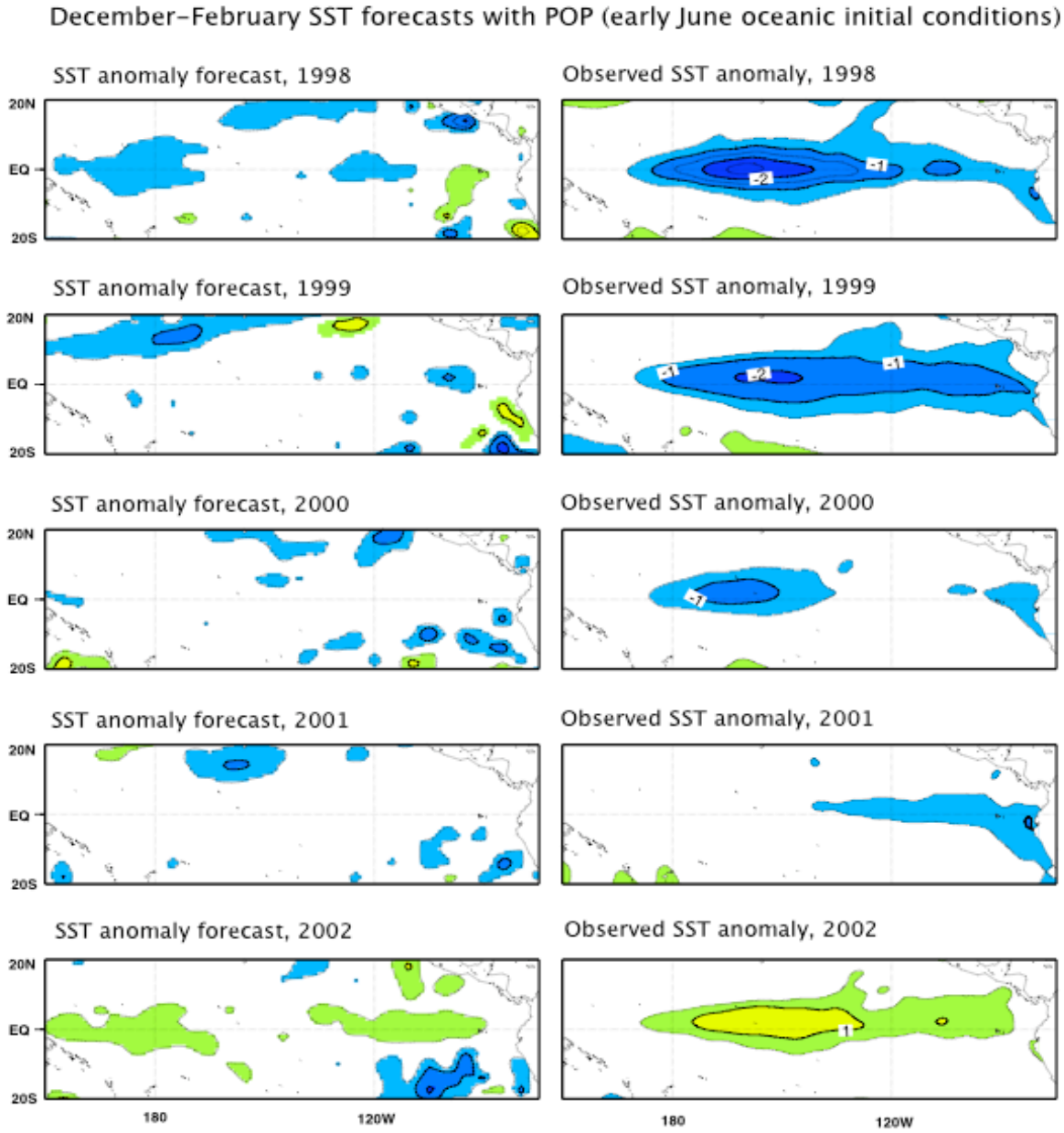


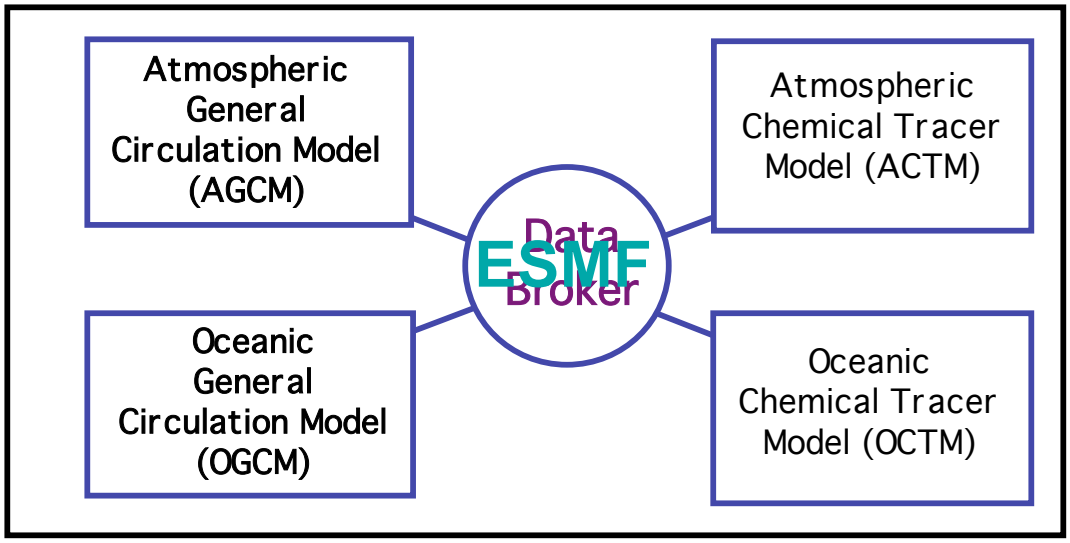
Contour interval: 1º C; +/- 0.5º C contours are also shown.

UCLA AGCM - LANL POP



UCLA AGCM - LANL POP





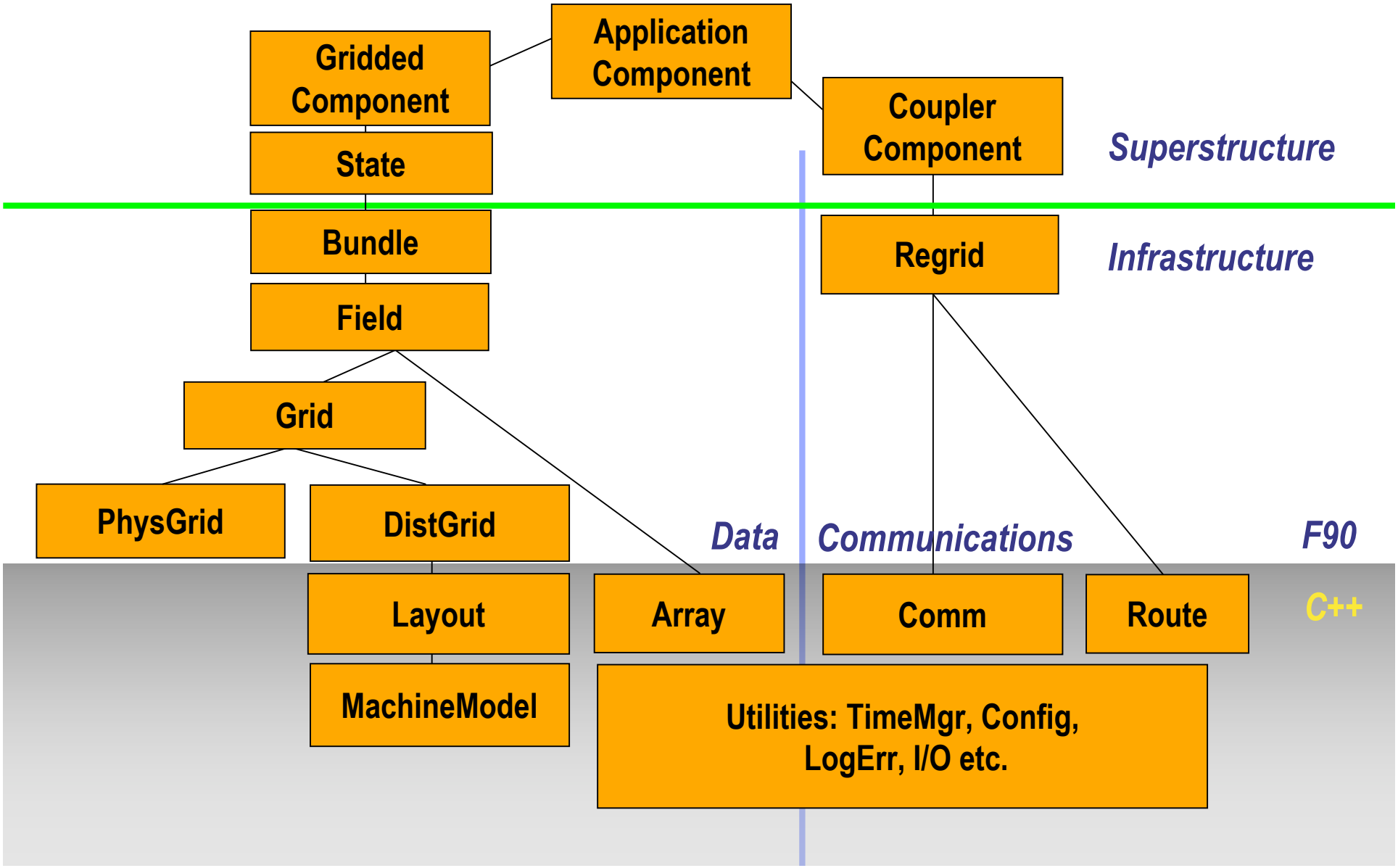
UCLA Earth System Model

Model components:

- *UCLA AGCM with upgraded PBL parameterization*
- *LANL Parallel Ocean Program (POP) and MIT OGCM, both in a quasi-global domain with the same grid.*
- *UCLA ACTM (which can include up to 64 species)*
- *Simple NASA/JPL Ocean Chemical Transport Model*

UCLA

ESMF Class Structure

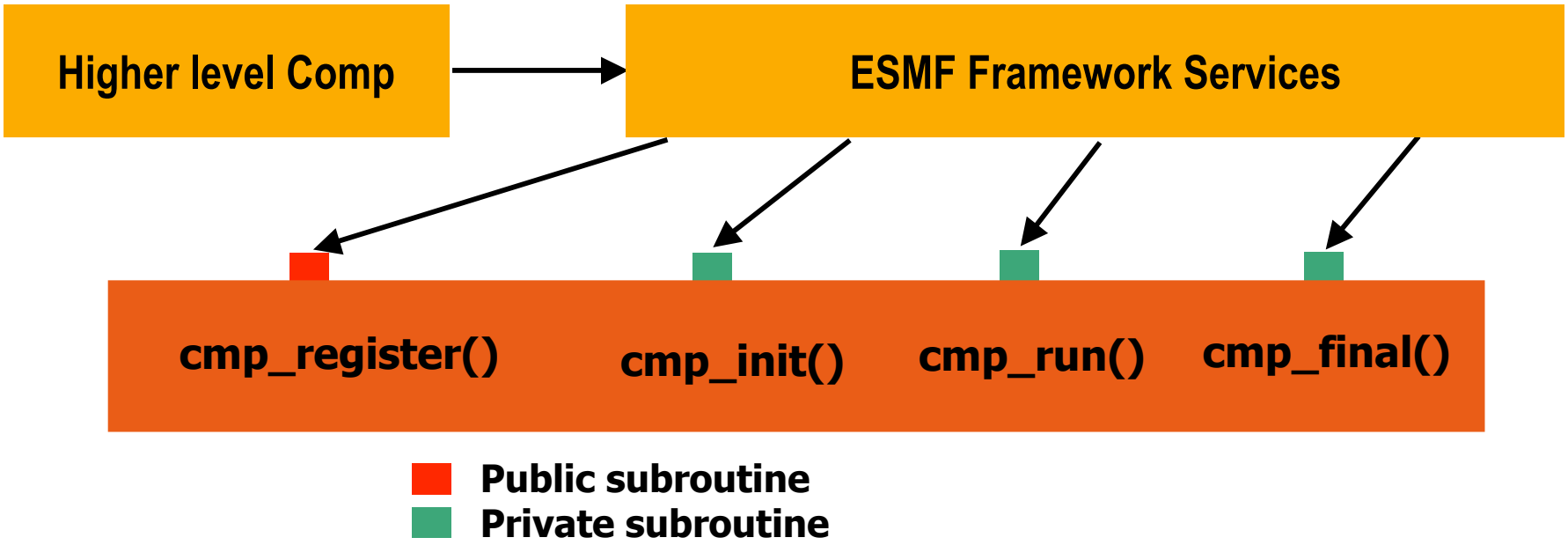


ESMF Component Registration

Components provide a single externally visible entry point, which register the other entry points with the ESMF. Components can:

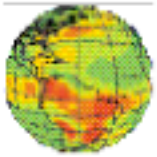
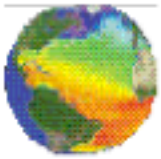
-Register one or more Initialization, Run, Finalize, and Checkpoint entry points.

-Register a private data block which can contain all data associated with this instantiation of the Component.



Porting Strategy

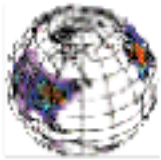
1) Model codes (AGCM, OGCM) were restructured to isolate Initialize, Run and Finalize tasks (i.e., were made ESMF compliant)
2) An ESM Driver Program (EDP) was created to control the sequence in which those Initialize-Run-Finalize tasks and data transfers are executed, as well as to keep track of simulation time.

The AGCM as ESMF Compliant

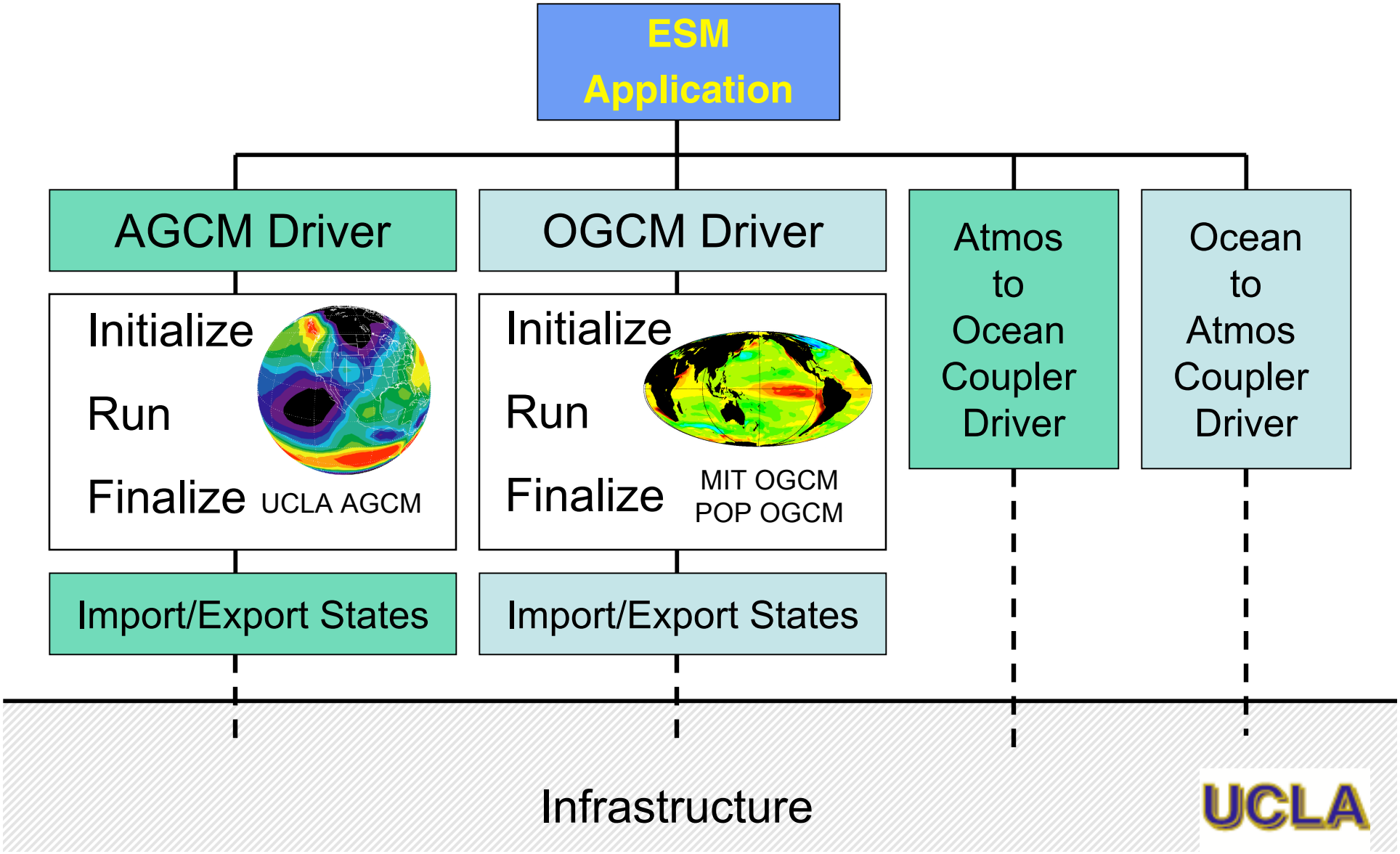
```
Module AGCM_GridComp

     AGCM_Initialize
     AGCM_Run(start time, end time)
     AGCM_Finalize
```



UCLA

Coupled Atmosphere-Ocean Application in ESMF- Superstructure



ESM Application

Register components
Create data bases

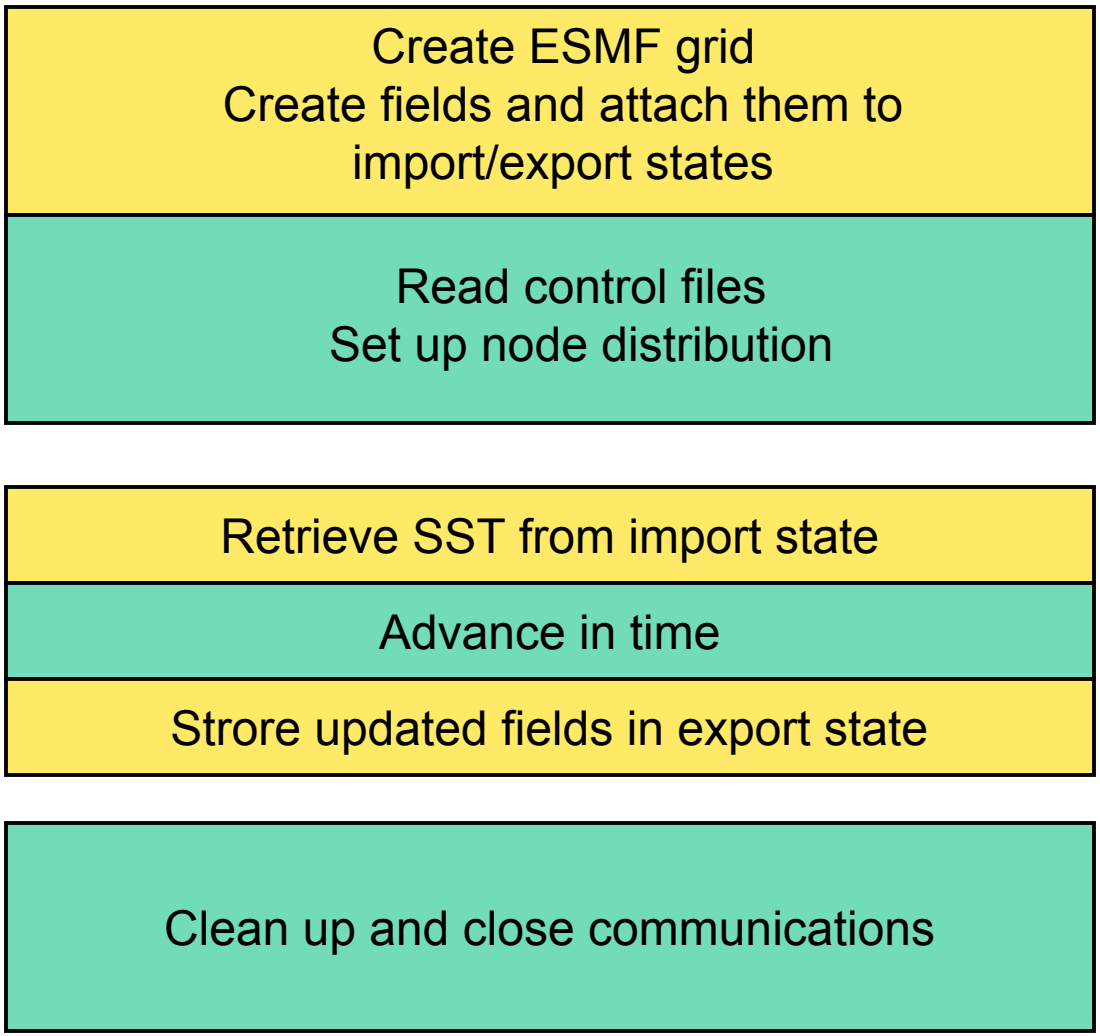
Initialize components

Call gridded components drivers (time advance)
Call coupler components for regridding
and transfers

Call gridded components to perform
finalize functions

UCLA

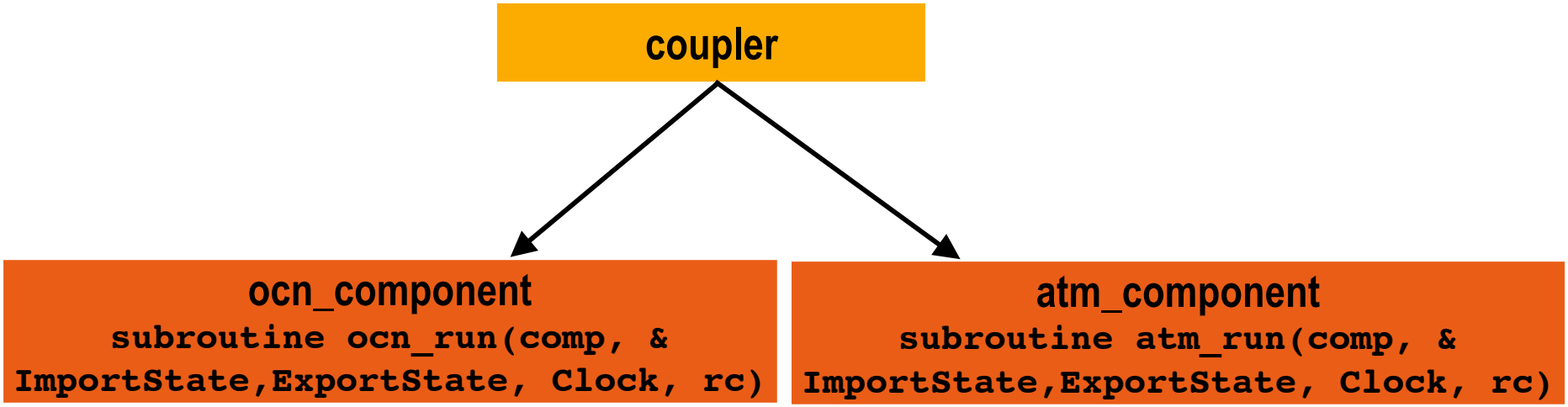
Component Driver in EDP (e. g., AGCM)

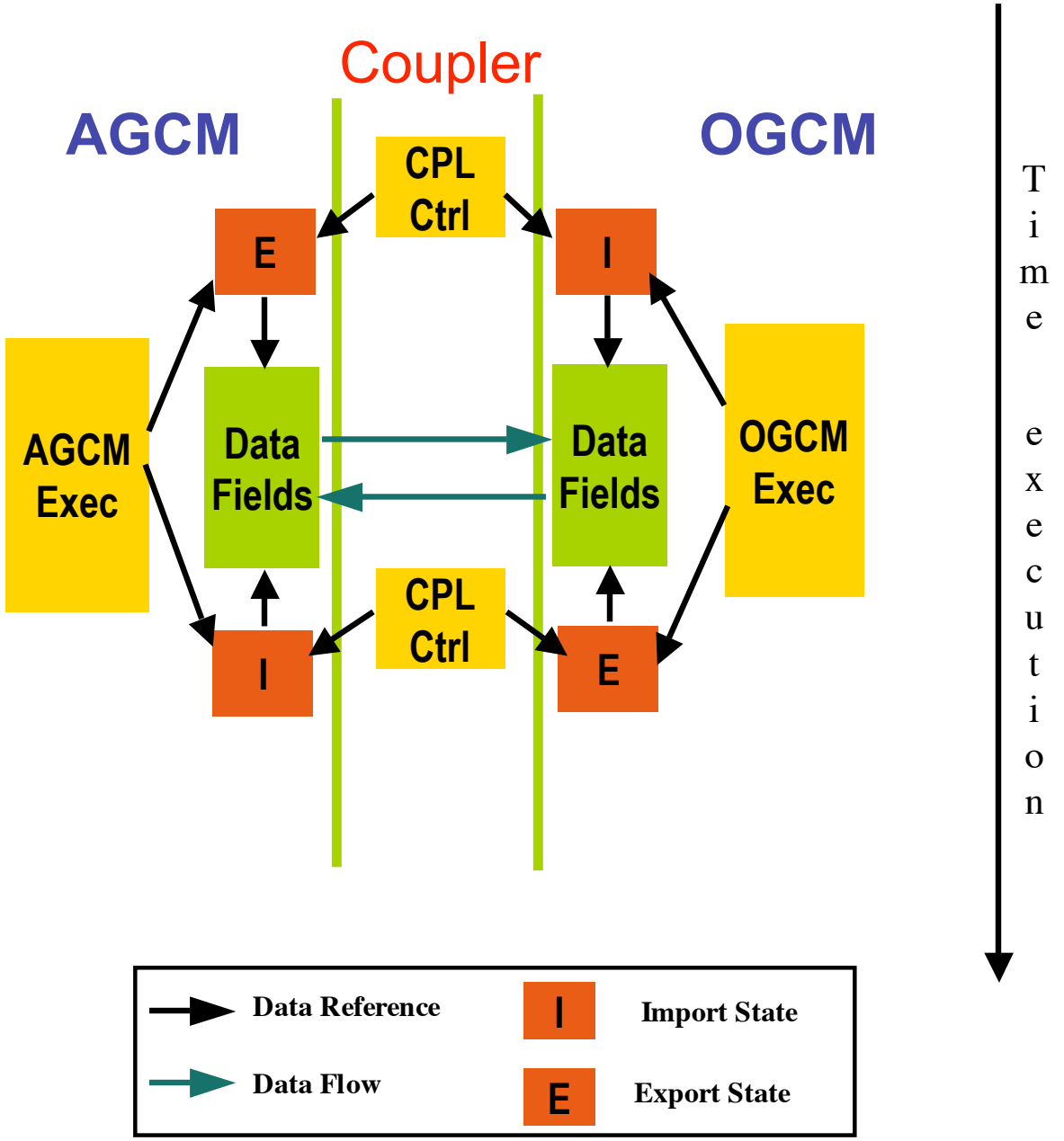


UCLA

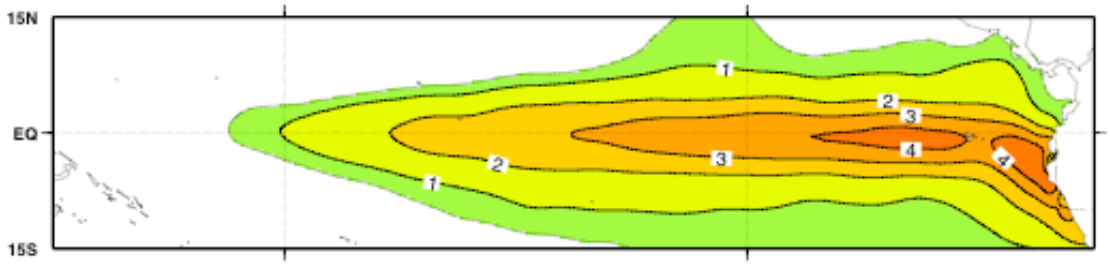
Coupler Components
Import/Export States

The AGCM does not have access to the internals of the OGCM, and vice versa. The exchange data is through a coupler component, which exchanges the roles of Export State from one component to Import State for the other component. The coupler components also do the grid transformations.

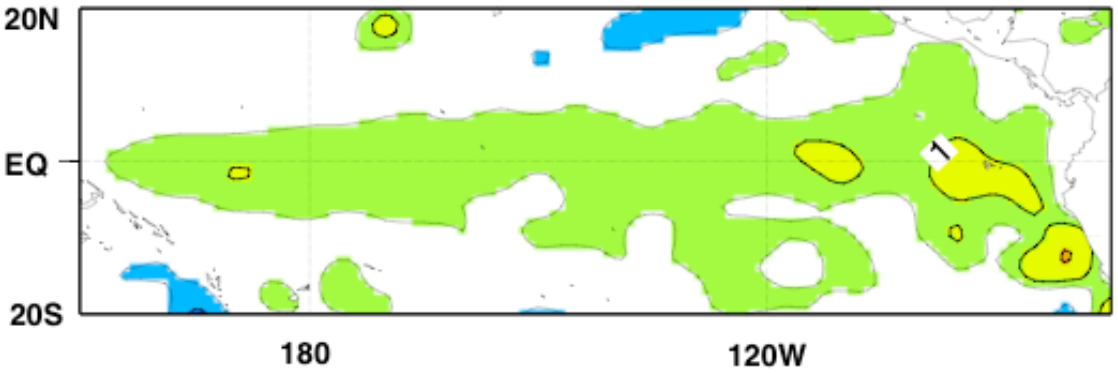



Coupler
AGCM
OGCM
CPL Ctrl
E
I
AGCM Exec
Data Fields
Data Fields
OGCM Exec
CPL Ctrl
I
E
Time execution
Data Reference
Data Flow
I
Import State
E
Export State

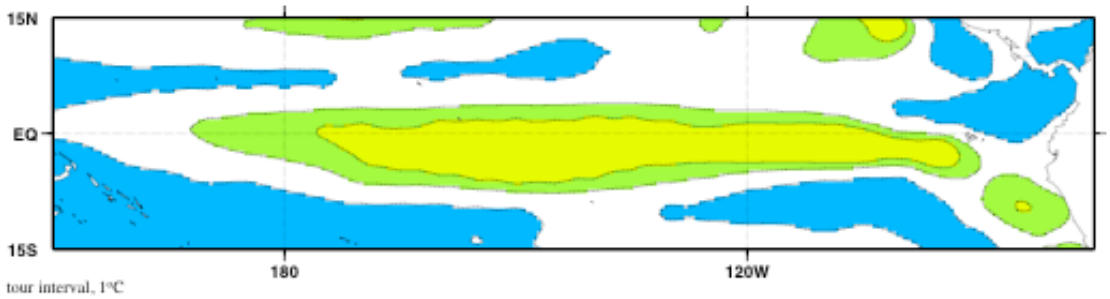
DJF 1997-1998 SST Anomaly Observation (Observation)



Without ESMF



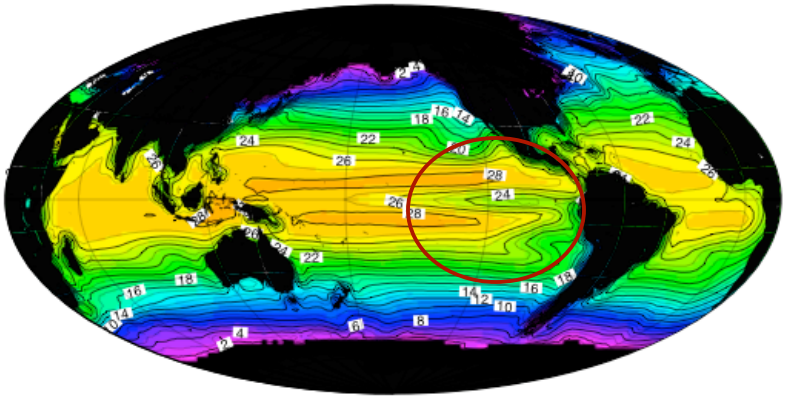
With ESMF (but some changes!)



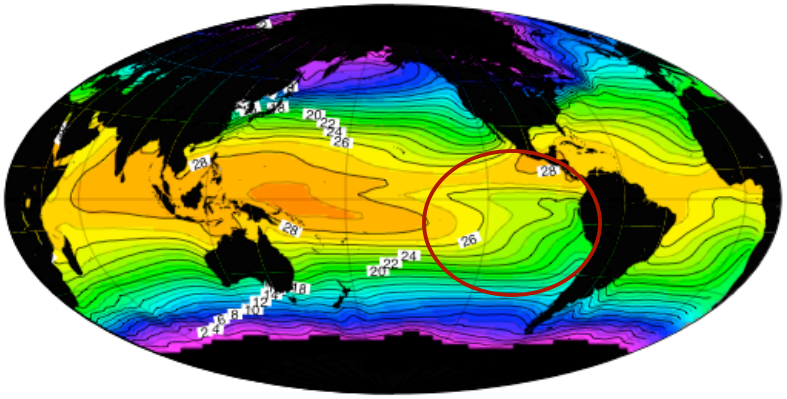
tour interval, 1°C

Annual Mean SST

Model



Observation

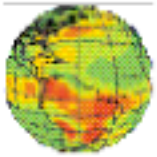
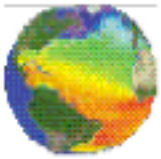


UCLA AGCM - MIT OGCM

"Double ITCZ" Problem

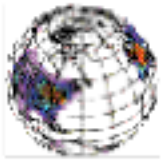
Hypothesis 1: Poor heat transport by ocean eddied from upwelling regions - Insufficient OGCM resolution?

Hypothesis 2: Poor simulation of the zonal circulation - Difficulties in the simulation of resolved and subgrid processes?

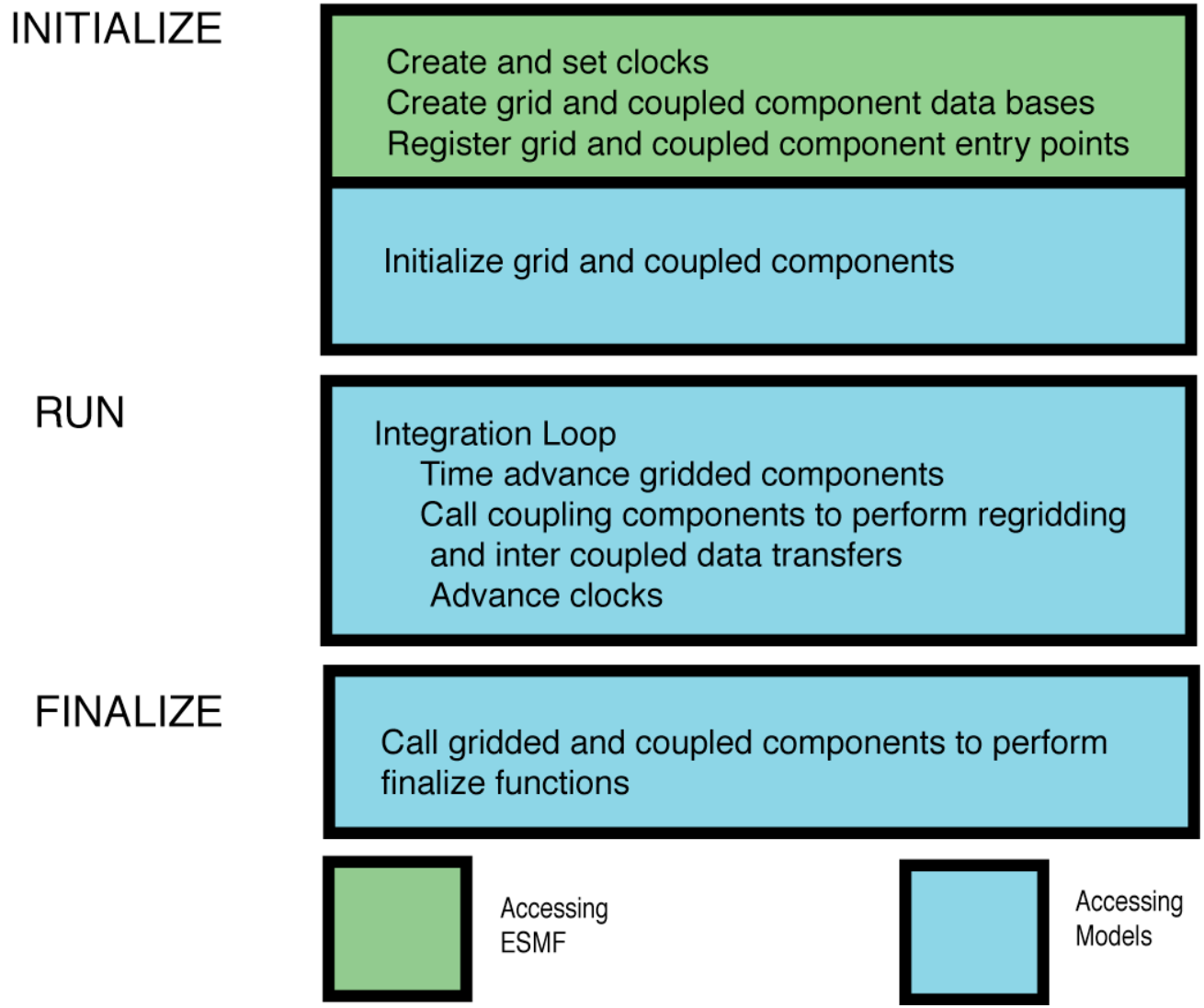
SUMMARY

- The coupled atmosphere-ocean model shows skill in ENSO prediction from six months in advance. The skill is higher for the UCLA AGCM/MIT OGCM combination.
- The UCLA AGCM was coupled to the MIT OGCM and LANL POP using ESMF services.
- The most time demanding task was to make the model components ESM compliant.
- Much more work with the ESMF is needed for debugging, increased capability and user friendliness.
- Model codes integrated into the ESMF require maintenance if the framework is to become a standard for Earth System Modeling.

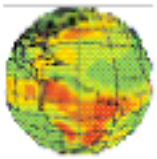
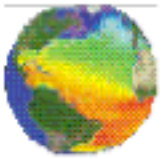


UCLA

ESM APPLICATION



UCLA

Component Driver in EDP (example AGCM)

INITIALIZE 1

Initialize intra mode communications
Initialize AGCM
- Read control files
- Set up model geometry and decomposition
- Allocate variable storage

Create ESMF grid for the AGCM gridded component
Set grid decomposition (node geometry)
Create fields and attach them to import and output states

INITIALIZE 2

Retrieve initial SST from import state

Read restart
Do first AGCM physics step

RUN

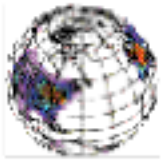
Retrieve SST from import state

Time advance

Store increments in export state

FINALIZE

Clean up
Close intra model communications



UCLA